AN Fe-Ni MELT RESIDUE DEPOSITED IN SPACE: A NEW CLASS OF MICROMETEOROID? G. A. Graham[1,3], A. T. Kearsley[2], M. M. Grady[3] and I. P. Wright[1], [1]Planetary Sciences Research Institute, Open University, Walton Hall, Milton Keynes, MK7 6AA, UK, e-mail: g.a.graham@open.ac.uk, [2]Division Of Geology & Cartography, School Of Construction & Earth Sciences, Oxford Brookes University, Gipsy Lane, Headington, Oxford, OX3 7AB, UK, [3]Department Of Mineralogy, Natural History Museum, Cromwell Road, London, SW7 5BD, UK.

Abstract: A melt residue identified in an impact crater recovered from the Hubble Space Telescope (HST) consists solely of Fe-Ni metal globules set within the melt glass of the host. The composition of these globules is 93.4 ± 1.8 wt% Fe and 6.4 ± 1.8 wt% Ni, with trace Mn. There is no Cr signal which would suggest that it is not an artificial particle of space debris in origin The composition is well within the range of kamamcite a metal precursor recorded from iron meteorites and suggests that the impactor could be a primary iron-nickel micrometeoroid. This is the first time that such an entity has been identified and raised the question as to why such samples are not recognised in the stratospheric Interplanetary Dust Particle (IDP) collections.

Cosmic dust particles collected in space (low Earth orbits) and in the stratosphere are termed IDPs and are generally smaller (<100µm) [1] than particles collected on Earth (generally >100µm, although smaller particles have been identified [2]) termed micrometeorites, which are subject to atmospheric and terrestrial alteration [1]. IDPs collected in the stratosphere [3,4] and intact particles collected from LEO [5,6] have been identified as chondritic in origin by the use of such techniques as energy dispersive X-ray ananlysis [1,3-6]. This means that the general identification of IDPs is that of olivine-, pyroxene-, and layer-silicate classes [1,7], with a subset consisting of nanometre aggregates of Mg-Fe silicates, Fe-Ni sulfides and Fe-Ni metal in a glassy or carbonaceous matrix [1]. Several IDPs collected in the stratosphere were initially identified as non-chondritc in origin [8]. However the elemental compositions and the petrology of these particles has been taken to imply that they are volcanic ash blown into the stratosphere and are therefore terrestrial in origin [8,9]. The natural impact residues identified from LEO collectors [e.g. 10,11] have elemental compositions which can be linked to those of intact IDPs and are thus probably chondritc in origin. Here we report on a impact residue from a (HST) solar cell [12] which has a distinctly non-chondritic composition, but appears not to be terrestrial in origin.

The solar cell was one of nine samples that have been investigated as apart of a generalised post-flight analysis program of HST space hardware [12]. The sample was initially examined under an optical microscope which identified an impact crater 100µm in diameter and extraneous black metallic material which was located within the crater bowl. The entire cell was carbon-coated and examined using a scanning electron microscope fitted with a energy dispersive X-ray spectrometer (the experimental protocols are described in [12]). Digital back-scattered electron images (BEI) and X-ray emission maps of the crater were produced and the identified residue subsequently analysed.

The BEI within the crater identified a number of bright spherical globules attached and embedded within the melt surface of the cell host. A high-magnification and high-pixel resolution X-ray emission map of this area established that the bright globules were almost solely composed of Fe-Ni metal whereas the surrounding area was composed of host melt (Si, K, Ca, Ba, Zn with minor Mg and Ce). X-ray microanalysis revealed that these tiny (<10µm) melt globules contain iron and nickel in an apparent-weight ratio consistent with the identification of kamacite (i.e., by analogy with iron meteorites where the Ni content of kamacite is <7.5 wt% [13]). The small size of the spherules along with the silicate melt matrix and the deep position within the crater prevent full analytical correction using ZAF routines. Nevertheless if the contaminant components are excluded from spectrum processing, and the transitions metals alone are subject to quantitative correction, the composition obtained for the bright globules is Fe 93.4 ± 1.8% by weight and Ni 6.4 ± 1.8 by weight, with trace Mn (mean and rmsd of 50 analyses each of 100 seconds in duration). Thus these values would suggest that the original impactor was a metallic Fe-Ni particle

It possible that the globules were derived from space debris such as a specialised steels used in the aerospace industry (e.g. satellites, rockets etc.). Such particles have been identified in LDEF studies [14] and in the stratospheric collection of IDPs as contamination [3]. The typical compositions of such steels is >70 wt% Fe, up to 14.5 wt% Cr and Ni between 6-8 wt% with minor Ti and Mo [15] The globules analysed contained no Cr, Ti or Mo even in minor amounts and the Fe content was appreciably higher (93.4 wt% ± 1.8). Thus suggesting that the particle is natural in origin.

In a previous study an Fe-Ni residue has been identified in a hypervelocity impact feature from LDEF [10], but in this these globules were appreciably smaller in size (<50nm) compared to the larger bodies identified here (<10µm) and were only identified under a transmission electron microscope. Furthermore these globules were associated with a ferromagnesian glass matrix [10], demonstrating that they are infact, inclusions within a more major matrix (which turns out to be chondritic in composition). Kamacite has also been identified in intact IDP but only as minor phases [11] and not as a major component that would suggest a metallic origin. It is possible that the Fe-Ni metal globules are from chondritic material (due to the size of the kamacite grains reqiured) from which the volatile elements such as magnesium and sulfur have been devolatilised on impact. This feature was noted in LDEF studies (e.g. [10]) where Mg-olivines were not located, and many of the impact pits displayed characteristic features of shock metamorphism [10]. We suggest here and in [12] that this is not the case and it maybe possible to retain such volatiles in the impact melt glass due to the rapid cooling which the residue undergoes. It has been shown [12] that the technique used can identify different melt states within a sample (e.g. the residue melt, the mixture of residue and host and the host). The example used in [12] is that of a Fe-Ni sulfide which was identified in several samples. Although it is fair to say that such a residue is resistant to metamorphic changes and has been identified in LDEF residues [1] it does highlight the fact that sulfides can be retained. Regarding other volatile elements such as Mg, Ca and Al the identification of such elements is complicated by the fact that these are all key elements within the composition of the solar cell. That said in several samples, Mg spectra and X-ray emission maps were obtained above the levels obtained expected for the recorded levels of the cells. These results were obtained in samples were the origin of the impactor was inferred as being a natural micrometeoroid and thus giving evidence that volatile elements can be identified in impact features. The fact that such volatile elements were not detected in this samples is because they are not present as a major component rather than because they have been removed during impact, that these Fe-Ni globules do not imply any chondritic origin. This is further supported by the distribution of the globules across the entire base of the impact crater, if they were from a chondrule, they would only appear in certain areas within the melt and would be smaller in size (similar to those in the LDEF melt [10]). In this sample not only do they cover the crater but the composition of the globules appears homogenous and are supported by a matrix that appears to be host material.

The reason why such a particle has not been identified in IDPs collected from the stratosphere, could be linked to the entry velocity of such particle as the collection method does have limitations [3]. Although further work would have to be carried out to assess the possibility of collecting such particles. The formation of such micron-sized droplets during asteroid collision might be questioned, although previous work [e.g. 16] suggest that such spherules can originate for these collisions.

Another Fe-Ni particle identified in a sample of the thermal insulation blankets of the EURECA spacecraft [17] will now be re-examined to provide confirmation of this discovery. It is proposed that the residue undergoes analysis by ion microprobe which would enable the analysis of the trace elements within the globules particularly Ge. Although it is likely that present techniques would be unable to deal with the small size of the globules.

We have identified a Fe-Ni residue (i.e. the result of a hypervelocity impact) in a solar cell from the HST. If true, it is necessary to contemplate why metallic particles are not found in the stratospheric IDP collection. It is known that micrometeorites collected in the ground are comprised of iron-nickel spherules [e.g 18]. These are thought to arise from chondritic starting material which have entered the atmosphere at high velocities and been subject to compositional and mineralogical changes [e.g. 18-20]. The identification of an Fe-Ni particle on space hardware demonstrates that iron-rich micrometeoroids may actual exist in space. As such we may have uncovered a new class of micrometeroid.

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